

## **Thermal Imaging Spectroscopy in the Kelso-Baker Region, California.**

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The primary objective of our study was to assess the ability of TIMS data to uniquely identify rock composition using thermal-infrared spectroscopy. For this study we selected a region with a wide range of rock and soil types in an arid environment, and compared the spectra acquired by TIMS to laboratory spectra of collected samples. A second objective was to use the TIMS data to study the potential for compositional mapping of Mars, the Moon, and other solar system bodies, in addition to the Earth.

To address these goals, a TIMS image was acquired of the Kelso-Baker region in the Mojave desert of California at a surface resolution of approximately 7 m. The image covers a range of mapped rock compositions, including the Cima volcanic complex, composed of basalt/andesite flows, the quartz-rich Kelso sand dunes, and a suite of carbonates, quartzites, and metamorphosed sedimentary rocks in the Kelso mountains, as well as a range of alluvial materials. Each of these components can be readily distinguished based on variations in their spectral properties over the six TIMS bands. We generated a principal component image of the region using bands 1, 3, and 5, and applying the technique described by Kahle and Rowan (1980) and Kahle and Goetz (1983). This image was then used to map the areal extent of each geologic component. These units were compared to existing geologic maps of the area to determine the ability of TIMS to reproduce and improve the mapping capabilities obtained by direct field investigation. This study revealed subtle compositional distinctions not previously mapped and, as has been reported previously (Kahle and Goetz, 1983; Gillespie et al., 1984), the TIMS data in many cases greatly improved the location of geologic contacts and identified small outcrops not previously mapped. Using the unit map derived from the TIMS data, a field reconnaissance was conducted in May, 1985 to investigate the cause of the variations in spectral properties and to collect samples for laboratory analysis.

### **TIMS Spectral Analysis**

Using data from each of the six TIMS bands, spectra of the major units in the area were made. These spectra were generated from data calibrated for instrument response. Each spectral point was determined by averaging over areas three pixels by three pixels in size. Examples of these spectra are shown in Figure 1. Figure 1a gives the data offset in emissivity for clarity; Figure 1b shows the same data plotted with no offset. The emissivity scale is approximate, based on preliminary estimates of surface kinetic temperature.

### **Field Studies**

A variety of surfaces were examined to determine the composition of the rocks present and to study the origin of the units characterized by the TIMS data. The region can be roughly divided into three geologic provinces using the TIMS data alone. These consist of the basalt flows at the north end of the region, the high-silica sand dunes to the south, and the sediments and meta-sediments in the center portion of the study area.

The sand dunes have a very high silica content, as can be seen from the six-point spectra extracted from the original TIMS images (Fig. 1). The spectral character of the dunes varies across the field. However, this variation is due to changes in the depth of the absorption band centered at  $9.2\ \mu\text{m}$ , rather than in the position of the band center (Fig. 1). Field investigation revealed that these changes are produced by variations in the abundance

of vegetation, which appears to be essentially blackbody in nature. Therefore, the vegetation reduces the spectral contrast, but does not introduce a second spectral component. Using the TIMS data alone, the active, vegetation free regions of the dunes can be readily distinguished from the inactive regions stabilized by plant cover. Because of the strong differences in the spectral properties of quartz sand and vegetation, TIMS provides a useful tool for remotely distinguishing regions of unvegetated, active sand from regions with low (~10%) plant cover.

The Cima basalt flows in the northern portion of the area appear very uniform in both the TIMS image and the six point spectra (Fig. 1). Even when this area is isolated, a principal component stretch is performed on this region alone does not reveal significant variations. The composition of these flows does not appear to vary significantly throughout the field, consistent with the uniform spectral signature observed by the TIMS data. However, field investigation showed that a wide range of surface textures and particle sizes do occur on these flows. The surfaces observed included fresh, relatively unweathered aa lavas, with up to 1.5 m of surface roughness, as well as smooth, desert pavements composed of basalt fragments that cover up to 90% of the surface, and smooth deposits of 1 to 5 mm cinders. These observations indicate that surface texture does not play an important role in controlling the thermal emission characteristics in this area. This finding has important implications for extrapolation of thermal-IR spectral measurements to other regions and to other planetary surfaces. For this region, composition, rather than texture, controls the observed thermal-IR spectral properties.

These greatest compositional variability occurs in the combined suite of sediments, meta-sediments, and igneous intrusives of the Kelso mountains. Several units are easily distinguished spectrally (Fig. 1), including carbonates and quartzites. Of particular interest is a suite of rocks that have been mapped together as pre-Cambrian metamorphic rocks. This suite is readily separated into different units using the TIMS data. Field investigation of these units revealed them to be a range of silica-rich igneous and metamorphic rocks that had subtle differences in the composition and abundance of mafic and feldspar components. These subtle differences can be identified in hand specimens of the different units, but the distinctions are not simple, nor readily apparent. The increased abundance of mafic minerals in the metamorphic rocks can be seen in the spectra (Fig. 1) as an absorption band near 9.8  $\mu\text{m}$ . The quartz minerals also produce an observable absorption band between 8.8 and 9.2  $\mu\text{m}$ , as can be seen by comparing the spectra of this material to that of the quartz sand dunes. Therefore, it is possible to infer the general composition of these rocks as containing both abundant silica rich and mafic minerals from the TIMS spectra alone, although at present no attempt has been made to estimate the abundance of these components from the TIMS spectra alone.

In summary, the TIMS data provide an excellent means for discriminating and mapping rocks of very similar mineralogy. The spectra obtained from the TIMS data demonstrate the differences in absorption band location and strength between rocks different rock types, and confirm that there are systematic differences. Qualitatively, the spectral character can be used to predict the dominant mineralogy of these rocks. These predictions are confirmed by hand specimen and laboratory spectral analysis. For the rocks in this study area, it is composition, rather than particle size or surface texture, that controls the thermal emission characteristics. These findings suggest that thermal-infrared spectroscopy can provide a powerful tool for identifying and mapping rock composition on the Earth and other terrestrial planets.

## References

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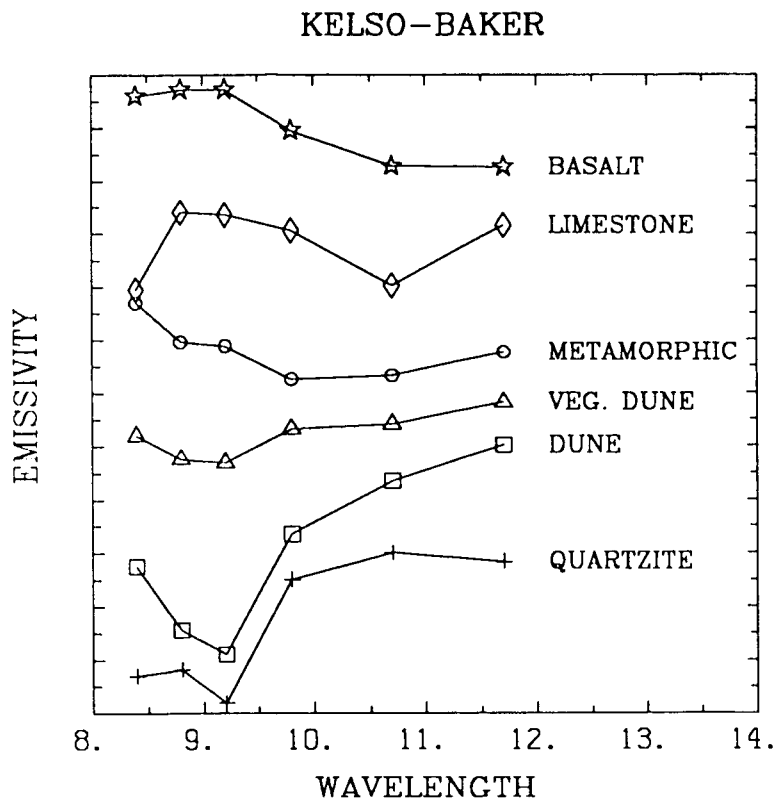


Figure 1a. Six-point spectra extracted from TIMS image of rock units in the Kelso-Baker region, California. Spectra are offset in emissivity for clarity.

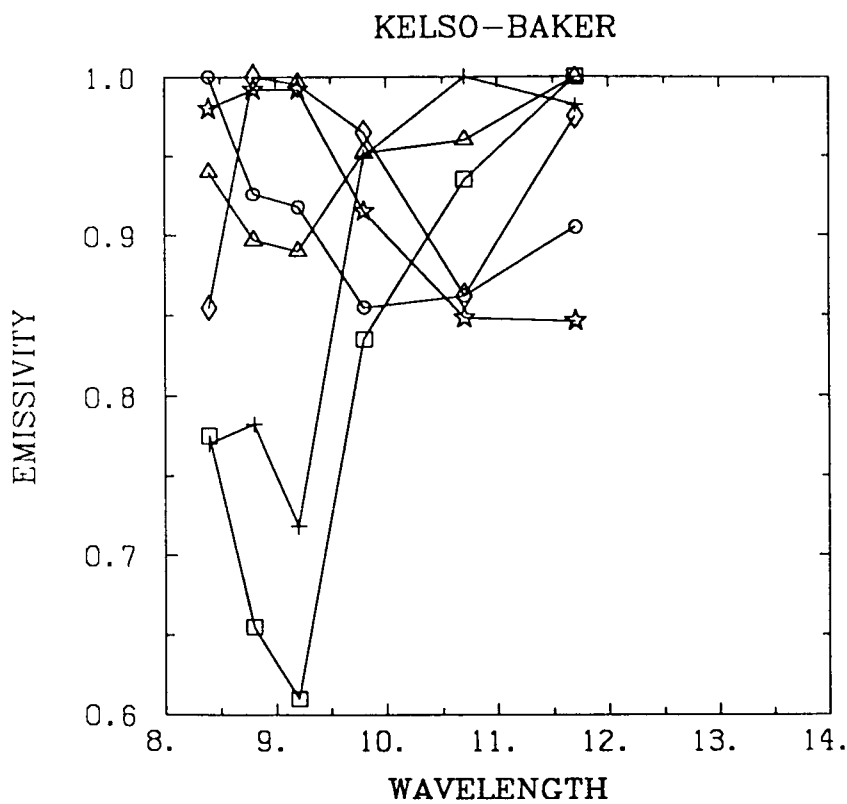


Figure 1b. Same data shown in Figure 1a, but with no offset in emissivity.